EECS 373 - Homework #5 - Solutions

Name: ______________________________ **unique name:** ________________

For this assignment, make a copy of this Google Doc and use the answer boxes provided to fill in the answers to the questions. The source file for this document can be found on the class website. Students are encouraged to type out their answers, but neatly handwritten answers will also be accepted where appropriate. Gradescope is set up to accept variable length assignments. Once students upload a PDF of their completed assignment to Gradescope they will need to designate where they responded to each question.

Question 1 - Short Answer [15 points, 3 each]

Briefly answer the following questions about about timers:

1.1) What is a "Crystal Oscillator" and how is it used for timekeeping?

Crystal Oscillator is a part to create precise clock.

1.2) Why are there so many different clock sources, clock dividers, and pre-scalers on the STM32?

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Question 1 - Short Answer [15 points, 3 each]

Briefly answer the following questions about about timers:

1.1) What is a "Crystal Oscillator" and how is it used for timekeeping?

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a constant frequency. This frequency is often used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators, but other piezoelectric materials including polycrystalline ceramics are used in similar circuits. https://en.wikipedia.org/wiki/Crystal_oscillator

1.2) Why are there so many different clock sources, clock dividers, and pre-scalers on the STM32?

Having the ability to select and in some cases dynamically control the timing of the MCU core and peripheral is incredibly important for modern embedded systems. Primarily there is a tradeoff between speed and power where lowering clock frequency is the main mechanism for reducing system power consumption. Secondly, it is often the case that the best clock speed for code execution is not the optimal clock speed needed to interface with peripherals or the outside world. Lastly, it is important to be able to accurately keep track of the passage of time using timers and counters, however the clock frequency needed to best for this application is often different then needed for code execution.

1.3) In your own words what is Pulse Width Modulation?

Pulse Width Modulation is a commonly used signal type in embedded systems consisting of a repeating set of square digital pulses that transition from VDD to GND. The width of the pulse is typically varied while keeping the period fixed in order to encode timing information. Applications include controlling LEDs and the position of Servo motors.

1.4) Explain the difference between a *Capture* timer and a *Compare* timer, and give examples of what they are used for?

A Capture timer latches in the value of a free running timer when an external event or trigger has occurred. They are often used to measure intervals between external events.

A Compare timer is used to compare if the current value of a free running timer is equal to a given value. If so an interrupt can be triggered or other action can be taken. Compare timers are often used to generate PWM signals or as an "alarms clock" that triggers an event at a given timer value.

1.5) What is the function of an Auto-Reload Register and what is it useful for?

The auto-reload register can be used in a variety of ways. In the case of PWM, it often holds the value of the period, while the compare registers hold the value of the pulse width. For instance, the timer could be placed in decrement mode and start at the particular value representing the period of the waveform. When the counter hits the compare value the MCU is programmed to transition the output waveform. The timer will proceed until it hits zero when it underflows resulting in the output waveform transition back. Here the auto-reload register reloads the timer start value and the procedure repeats thus allowing a continuous train of a pulse at a particular width and period.

Question 2 - Timers [20 points]

Consider a situation where you need to have multiple timers working simultaneously to monitor and sample a sensor suite, as described below:

- Two wires carrying sound signals that must be sampled at 44.1 kHz (the sample rate for a CD).
- A button that must be sampled at 200 Hz.
- A temperature sensor that must be sampled every three minutes.
- An I2C data line that must be sampled at 400 kHz.
- There is one clock signal at 20 MHz, shared between two 32-bit hardware timers.

Virtual

3 min.

Describe how to use the two 32-bit hardware timers to handle monitoring and sampling all five sensors, using additional virtual timers. Please include the 32-bit count register initial values of each of the hardware timers. Describing what is done with the sensors' data is not necessary.

2.1) Hardware Timer 1 [5 points]

$20MHz / 50 = 400KHz$. → 用于I2C.

ARR

2.2) Hardware Timer 2 [5 points]

$\frac{20MHz}{44.1KHz} = \frac{20\times10^3}{44.1} = 453.5 \approx 454$

ARR = 454. → 用于 CD.

$\frac{1}{200}S$

200HZ.

2.3) Virtual Timer [10 points]

3min task → 用 timer 1 400KHz.

400KHz

$\frac{1}{400K}S$

Virtual Timer 其实是 fixed timer count 到顶之后记录多少次.

400KHz. 3min → 180S.

$\frac{1}{400K}S$

$\frac{180S}{\frac{1}{400KS}} = 180 \times 400K = 7200000$

$\frac{\frac{1}{200}}{\frac{1}{400K}}$

$\frac{400K}{200} = 2000$

Question 2 - Timers [20 points]

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Describe how to use the two 32-bit hardware timers to handle monitoring and sampling all five sensors, using additional virtual timers. Please include the 32-bit count register initial values of each of the hardware timers. Describing what is done with the sensors' data is not necessary.

2.1) Hardware Timer 1 [5 points]

Set the max value to 50, which generates an interrupt at 400kHz. Use this to sample the I2C data line.

2.2) Hardware Timer 2 [5 points]

Set the max value to 454, which generates an interrupt approximately every 44.1kHz. Use this to sample the audio.

2.3) Virtual Timer [10 points]

A virtual timer 1 with a max value of 36,000 whose counter increments on the interrupt generated by Hardware Timer 1. This gives a frequency of 0.0055556Hz(period = 180s). Use the interrupt generated by this timer to sample the temperature sensor.

A virtual timer 2 with a max value of 2000 whose counter increments on the interrupt generated by Hardware Timer 1. This gives a frequency of 200Hz. Use the interrupt generated by this timer to sample the button.

Question 3 [10 points]

Pulse Width Modulation. Suppose a HSE (High Speed External Clock) of 16MHz is selected as the clock of the timer. In order to generate a 1Hz square wave with a duty cycle of 50%, how would you set up the timer? Indicate your counting mode and show the value of ARR, CCR and PSC registers. [5 points]

HSE : 16MHZ. $\longrightarrow$ 1HZ ⎍ duty cycle : 50%.

need: ARR / CCR. / PSC.

counting up. PSC = 16000 − 1 = 15999

$$\text{Clock} = \frac{16\,MHZ}{16000} = 1KHZ.$$

$$\text{period} = 1\,HZ \qquad \frac{1KHZ}{1HZ} = 1000 = ARR - 1.$$

ARR = 999

Since Duty cycle = 50%

CCR = 1000/2 = 500.

Question 3 [10 points]

Pulse Width Modulation. Suppose a HSE (High Speed External Clock) of 16MHz is selected as the clock of the timer. In order to generate a 1Hz square wave with a duty cycle of 50%, how would you set up the timer? Indicate your counting mode and show the value of ARR, CCR and PSC registers. [5 points]

Multiple possible solutions: The solution is not unique.

Solution 1:
ARR = 1000 - 1 = 999
CCR = (1+ARR)/2 = 500
Timer counter clock frequency = 1Hz * (1 + ARR) = 1000 Hz
PSC = 16 MHz/(1000Hz) – 1 = 15999